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December 19, 1995

Distribution

Enclosed is a working draft report describing potential exposure scenarios that could be used for the Human Health Risk analyses of the Columbia River Comprehensive Impact Assessment. This report is being transmitted to you for your review prior to the informal workshop on scenario development scheduled for 9:00 - 5:00 on January 3, 1996 in Richland.

I have quickly prepared this report to start everyone's thinking about the pathways and parameters we will be addressing in our workshop. As I mentioned in the meeting on December 12, a good start had been made in this direction by PNL staff working on the Integrated Risk Assessment Project (IRAP) for the Department of Energy's Planning and Integration Division. The authors of that IRAP report graciously provided me with their draft, which I have plagiarized mightily. As I have noted on the cover of the report, most of the credit for the status of this effort goes to them - and we can put the responsibility for misinterpretation and incompleteness on me.

I would like to base the activities of our January 3 meeting on the scenarios proposed in this report. In particular, I think that I will start with Section 4.1 since I think that it is the most critical. Then, depending on the amount of time we have, I'd like to work through Sections 3.1, 3.2, and 5.0. I plan to have a computer with the equations of Section 6.0 built into a spreadsheet, so that we can attempt to work a few sample cases as a group. This should help us understand the relative importance of many of the parameters and thus help us focus on the most important parts of the scenario descriptions.

Sincerely,

B A Napier

Bruce Napier
Staff Scientist
HEALTH DIVISION

BAN

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Distribution

Please note: The attached document has neither been reviewed nor edited nor formatted. Its purpose is solely to act as a catalyst for discussion at the January 3, 1996 meeting.

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Letter Report

Draft Hanford-Specific Exposure Scenarios for Non-Remedial Activities that Might Occur Near the Columbia River

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* This draft is based heavily on earlier work by the following authors. I have placed my name first, not to claim credit for the significant efforts of the others, but to indicate responsibility for the various inadequacies of this version.

Executive Summary

This report is a first look at potential Hanford-specific exposure assumptions for Industrial; Wildlife Refuge/Wild and Scenic River Corridor; Native American; and Residential and Agricultural land uses. Exposure scenarios for specific activities that might be associated with those land uses were defined using local information when possible. In addition to the HSRAM Industrial (unmodified), HSRAM Recreational (unmodified) exposure scenarios, and HSRAM (modified) residential and agricultural scenarios, this report develops *draft, unreviewed* scenarios for the following activities: Fish Hatchery Worker, Ranger, Hunter, Native American (subsistence), Native American (hunting/gathering/fishing), and Native American (cultural/non-subsistence). It must be emphasized that these are strawman scenarios that have not received review or approval; they are intended solely as a starting point for discussions with Site user groups.

<u>Next Steps</u>.

(1) The exposure assumptions need to be reviewed by internal and external groups.
(2) Any additional exposure scenarios for actual Hanford on-Site activities need to be developed, as identified by internal/external review.
(3) Sensitivity analysis (with fate and transport model review) using actual Hanford contaminants needs to be done.

1.0 Introduction

1.1. Purpose

The present report takes various potential land uses (Wildlife Refuge, Native American uses, Industry, Research/Office, and General Recreation), identifies associated human activities (hunting, fishing, and so on), and develops an initial set of human exposure scenarios that reflect those specific activities that may be applicable at Hanford along the Columbia River. These exposure scenarios are intended to provide a starting point for discussions with various "user groups," including tribes and stakeholders. Additional scenarios applicable off of the Hanford Site are also included.

The development of human exposure scenarios is tied to particular activity patterns desired by specific user groups. For example, if Wildlife Refuge is a potential land use, the activities associated with that use might include Ranger, Hunter, or Recreational Visitor. Each of these three activities would involve different degrees of contact with environmental media, and only the Hunter would consume biota obtained on Site. Therefore, the exposures and risks to these three types of people could be quite different.

The purpose of this letter report is to illustrate the range of activities possible under restricted access. This is done by providing an example of how human chronic exposure scenarios could be developed. The scenarios are partially Hanford-specific (based on interviews and review of information about current on-going activities). The goal is to develop realistic and Site-specific scenarios. *Because these scenarios have not been reviewed, they should be considered a strawman set for stakeholder and internal review.*

This report complements the assessment of ecological and socio-cultural risks by providing a method for estimating human exposures that could occur during the same alternative land uses and human activity patterns specific to socio-cultural user groups.

1.2 Rationale for Developing Activity-Based Exposure Scenarios

Because a wide variety of potential uses of Hanford areas have been suggested, knowing the risks associated with a wide range of human activities may be useful.

At present. only two exposure scenarios are currently available in HSRAM for use at Hanford: Industrial and Recreational. However, a variety of land uses and human activity patterns at Hanford could be envisioned, ranging from industrial use to conservation and Native American uses. For this report, exposure scenarios were developed to reflect a range of specific activities in order to determine which activity patterns produce differences in human exposure significant enough to help discriminate risk from a human exposure perspective.

The goal in developing the scenarios below was to make them as Hanford-specific as possible. For example, information about actual time spent on Site by fish hatchery workers was used, as was information about actual hunting practices in the counties surrounding Hanford. Not all activities currently occurring on Site were evaluated. For example, B Reactor tours are being conducted; this is an activity for which predicted exposure information might be desired in the future.

It should be noted that these exposure scenarios are activity-specific, and not location specific. In actual practice, the application of these exposure scenarios to particular locations on Site requires that some assumptions be made about identification of residual contamination and any resulting mitigation actions.

Note that these exposure scenarios were selected based on general discussion and do not represent recommendations as to actual land use or cleanup levels. Also, neither the list of potential activities nor the specific exposure assumptions and parameters have received any external review (and only limited internal review). They are intended solely as starting points for discussion.

The draft exposure scenarios included in Sections 2-5 of this report are as follows:

Section 2. Industrial/Commercial Scenarios

Fish Hatchery Worker
HSRAM Industrial (unmodified)

Section 3. Wildlife Refuge/Wild and Scenic River Corridor Scenarios

Ranger
Hunter
Visitor with River-focused activity set (boat, swim, fish, etc.)

Section 4. Native American uses/ Eco-Cultural Preserve Scenarios

Subsistence (an unrestricted use included as a baseline for comparison)
Hunting/Fishing/Gathering/Collecting/Pasturing
Cultural/non-subsistence
Island uses (for application to Co-60 particles)

Section 5. General Scenarios

HSRAM unmodified recreational
HSRAM residential with irrigation explicitly added
HSRAM agricultural with irrigation explicitly added

The important points about the exposure scenarios are as follows:

- these scenarios are intended to include the activities of most importance to particular socio-cultural "user groups," and to translate them into activity-based exposures;

- each of the scenarios contains assumptions about frequency and duration of the activities, ranging from a few days per year to much more intense use over long time frames. The particular assumptions are specific to individual scenarios and will need to be reviewed by the major user group;

- these scenarios are amenable to sensitivity analysis and Monte Carlo uncertainty analysis, which together could demonstrate the relation between contaminant levels and activity-specific exposures.

- even though the scenarios appear to provide a greater level of precision and discrimination than the few scenarios that are in current use, this may or may not turn out to be true after testing them with actual contaminants in a hypothetical situation or with an actual waste site.

- these scenarios include Hanford-specific information, but they have not been reviewed. THESE SCENARIOS ARE NOT APPROVED FOR SITE USE.

2.0 Non-Remedial Worker Scenarios

2.0 Introduction

Industrial, commercial, and waste management activities are applicable both on and off of the Hanford Site along the Columbia River. The worker scenario developed in HSRAM is a standard industrial/commercial scenario focused on worker exposures to residual environmental contamination. For the scenarios in this section, only the potential exposure from contact with environmental media (as opposed to substances encountered as part of the job) were considered.

A Fish Hatchery worker scenario was developed in this section because of the current hatchery activities in the K-Area and at Ringold. The new scenario is benchmarked against HSRAM Industrial scenario. Documentation was provided, when possible, by employees working under these conditions. However, written data supplied by the interviewed employees has not been validated.

2.1 Fish Hatchery Worker

Currently the Yakama Indian Nation is conducting a pilot experiment in commercial aquaculture by rearing domesticated coho salmon and steelhead-X-rainbow trout in partnership with Scientific Ecology Group, a Westinghouse subsidiary. This scenario is included because these projects are expected to continue. Present and proposed future operations include development of a fish hatchery at the 183-K East and West Filter Plant, Sedimentation and Flocculation Basins, Coagulation Basins and the Purification Pools. This will be a hatchery similar in function and size of that being currently administered by the State Hatchery Program.

The Hatchery worker description is based on duties as described in the job classifications provided by the State Hatchery Program office for the Hanford experience as well as information gathered from the Eastbank State Hatchery in Ringold. The Eastbank Hatchery is a mid-sized operation which should be comparable to the size of the Tribal Hatchery in the near future. A state hatchery employee may work on a full-time permanent, full-time temporary and/or seasonal basis. A hatchery employee works an average of 200 days/year (estimated based on current staffing levels) and spends approximately 50-60% of working hours out-of-doors, as indicated by the job descriptions provided by the State Hatchery Program.

The greatest distinction from the standard scenario developed by the HSRAM is the exposure frequency. The rationale for exposure parameter values is as follows:

Soil Ingestion/Dermal/Inhalation The hatchery worker is assumed to ingest and/or inhale resuspended dust inadvertently during time spent on-site. The daily intake (100 mg/d and 20m3/d, respectively) is the same as the default values in HSRAM. Dermal contact with soil is increased to 1 mg/cm^2-d over the HSRAM value of 0.2 mg/cm^2-d.

Air Inhalation While on-site the Fish Hatchery worker may inhale fugitive dust from varying sources. The individual is assumed to inhale $20m^3/d$, identical to HSRAM.

Surface Water Ingestion/Dermal/Inhalation Ingestion of surface water occurs advertently from using processed Columbia River water as drinking water on site and inadvertently from surface water spray while working around the open water. For the present purposes, however, the HSRAM default value of 1 L/d for on-the-job ingestion was used. Frequent contact with the fish provides a route for dermal absorbtion; the value equivalent to dermal exposure during a typical 10-minute shower was used as a starting point.

Groundwater No contact with groundwater occurs at present for the Tribal Fish Hatchery Worker, although much of the water used in the Eastbank Hatchery comes from the (uncontaminated) Ringold Springs.

2.2 HSRAM Industrial Worker Scenario (Unmodified)

The HSRAM industrial scenario differs from Fish Hatchery worker scenarios primarily in exposure frequency and duration.

Table 2.1: Fish Hatchery Worker Scenario Exposure Factors

Pathway		Exposure Parameters[a]				
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Soil[b]	Ingestion	100 mg/d	250	30	1E-6 kg/mg	--
	External	8 hr/d	250	30	1.14E-4 yr/hr	0.8
	Dermal	0.2 mg/cm^2-d	250	30	1E-6 kg/mg	5,000 cm^2, ABS[c]
	Inhalation	10 m^3/d	250	30	1E-9 kg/μg	50 μg/m^3
Air[d]	Inhalation	10 m^3/d	250	30	--	--
Surface Water[e]	Ingestion	1 L/d	250	30	--	--
	External	8 hr/d	250	30	1.14E-4 yr/hr	0.25
	Dermal	1 hr/d	250	30	1E-3 L/cm^3	5,000 cm^2, K_p[f]

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on the skin (USEPA 1992).
d. Units for air concentration are pCi/m^3.
e. Units for surface water concentration are pCi/L.
f. Chemical-specific permeability coefficient (cm/hr).

3.0 WILDLIFE REFUGE/WILD AND SCENIC RIVER CORRIDOR SCENARIOS

3.0 Introduction

Designation of portions of Hanford as a Wildlife Refuge would require administration of the area by the U.S. Fish and Wildlife Service. This administration would be handled out of the Othello office of the U.S. Fish and Wildlife Service. Under this designation, no on-site continuous residence by humans is expected: an on-site facility would not be constructed to house rangers as part of the administration. The lands would be open to the public for a variety of uses, although no residential or agricultural uses would be permitted. The following recreational and scientific scenarios are possible under designation as a Wildlife Refuge (although not all of them were the basis of specific exposure scenario development):

- refuge ranger
- deer hunting
- bird watching
- fishing
- other and general recreational uses
- scientific study, monitoring and surveillance
- archeological study
- Reactor tour guide
- Intruder/vandal/trespasser

Recreational uses include many possible activities such as backpacking, picnicking, camping, bird watching, wildlife viewing, swimming, river boat touring, and water skiing. While there are no current plans for developing recreational facilities on the south shore of the Columbia River, possible development could include a boat-only overnight camping facility, self-guided auto tour routes, and hiking trails. If an Interpretive Center is built, suitable activities could be added to the list above and scenarios developed.

Public Law 100-605 directs the Department of Interior, in consultation with DOE, to make recommendations for preservation of the Hanford Reach of the Columbia River. One alternative considered is assignment of the Reach to the National Wild and Scenic Rivers System. If the Reach is designated a Wild and Scenic River, human exposure scenarios in addition to those provided in the HSRAM would be needed to assess risk. The first step in developing the new scenarios was to define Wild and Scenic River. The second was to understand what significant features would be protected under this classification. The last step was to determine what future land uses are possible given the definition and significant features.

The Wild and Scenic River Act (Public Law 90-542, as amended) uses the following definitions to designate Wild or Scenic areas. Wild River Areas are those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive, and waters unpolluted. These represent the vestiges of primitive America. Scenic River Areas are those rivers or sections of rivers that are free of impoundments, with shorelines and watersheds still largely primitive, and shorelines largely undeveloped, but accessible in places by roads.

The location of significant features is important when assessing an actual exposure pathway. Significant features of the area were determined in the Environmental Impact Statement (Hanford Reach of the Columbia River Comprehensive River Conservation Study and Environmental Impact Statement, 1994). Nationally significant features include:

- Fall chinook salmon and their spawning and rearing habitat.
- The intact ecosystem of the river and its adjacent land north to the ridgetop (Wahluke Slope).
- Federally recognized threatened or endangered plant and animal species
- Archaeologic artifacts of many indigenous cultures preserved along the river
- Hydrology and geology suitable for siting of nuclear reactors and radioactive wastes

Regionally significant features include:

- The White Bluffs along 31 miles of the north bank of the Hanford Reach
- The Ringold agricultural area
- Sport Fishing
- Hunting
- State endangered plants and animals
- Historic sites
- Flatwater Recreation

Uses allowed by the Wild & Scenic River Act would include:

motorized and non-motorized river craft
swimming/skiing
fishing
backpacking
picnicking
camping
bird and wildlife viewing
horsepacking
hunting
mountain bike riding (non-motorized)
ranching, grazing, farming, timber harvesting and occupation of homes as they exist on the date of the enactment

Several of these exposure pathways are covered under the HSRAM (DOE 1995) recreational exposure scenario (see Section 5). The scientific use scenario is considered to be included in the ranger and archeological study scenarios and is not included. Three scenarios have been selected for evaluation that should cover the range of potential exposures under the Wildlife Refuge and Wild and Scenic Rivers possibilities. These are refuge ranger, hunter, and river-focused visitor. The refuge ranger represents an individual who visits most habitat types on the site on a regular basis. The hunter is an individual who visits the site frequently to hunt for deer, waterfowl, and upland game birds, and ingests game taken. The river-focused visitor is similar to the hunter but spends more time directly on the river. The following sections describe the exposure pathways and parameter values for each of the three selected scenarios.

3.1 Refuge Ranger

In this scenario the ranger works out of an off-site facility and spends about three days per week on the site. While on-site he spends a third of his time in each of the habitat types: 1) upland range land, 2) long the shoreline, and 3) in a boat on the Columbia River). The ranger does not drink water from the site. The exposure scenario is very similar to the HSRAM industrial scenario except that less time is spent on-site. The ranger is assumed to work in the area for 20 years and spend 150 days per year on-site. The ranger is assumed to be stationed off-site because administration of Hanford as a Wildlife Refuge would be handled out of the Othello office of the U.S. Fish and Wildlife Service. A field facility on Hanford is unlikely to be established.

Soil Ingestion The ranger is assumed to ingest soil inadvertently during time spent on-site and in the field. The entire daily intake is assumed to be related to the site.

Soil Dermal Contact Dermal contact is assumed to occur associated with the inadvertent soil ingestion pathway. Soil adheres to the skin at a rate of 0.2 mg/cm^2 per day (one contact event per day). Contact occurs over a total surface area of 5,000 cm^2.

Soil External Radiation Exposure The ranger is assumed to be on-site 9 hours per day with a third of the time spent in each of three location types: shoreline, boating, and upland. The daily exposure period is set to 3 hours representing the time distribution for the ranger. A shielding reduction factor of 0.8 is applied (as per HSRAM).

Soil Resuspension and Inhalation Resuspension of soil with subsequent inhalation is assumed to occur at all times while the ranger is on-site. The amount of resuspension is determined by use of the mass loading approach based on an ambient air mass loading value of 50 μg/m^3. The pollutant concentration in the particulate matter in air is assumed to be the same as the pollutant concentration in soil. The ranger is assumed to inhale a total of 10 m^3 of air during the 9 hours while on-site. This provides an average daily intake rate of 10 m^3/day for the exposure analysis.

Air Inhalation While on-site, the ranger is potentially exposed to airborne contamination via inhalation. The ranger is assumed to inhale a total of 10 m^3 of air during the 9 hours while on-site. This provides an average daily intake rate of 10 m^3/d for the exposure analysis. The inhalation exposure occurs for all on-site activities and is included for the entire 9 hr/d.

Surface Water Boating External Radiation Exposure While the ranger is involved in boating activities, he is exposed to radiation emitted form contamination in the water. The exposure frequency is 150 days per year and one-third of the 9 hour work day (3 hours per day). A shielding geometry factor of 0.5 (Napier et al. 1988) is applied because the dose rate is evaluated using factors for total immersion in water (swimming) and while boating, the source is effectively one-half that of total immersion.

Sediment Ingestion Contact is assumed to occur with shoreline sediment while the ranger is involved in activities along the Columbia River. The contact rate is assumed to be the same as for general soil contact. An intake of 100 mg/d is assumed for the time spent along the shore, which is the total daily intake.

Sediment Dermal Contact Dermal contact occurs along with sediment ingestion and is evaluated in the same manner as soil ingestion. Soil adheres to the skin at a rate of 0.2

Table 3.1: Ranger Scenario Exposure Factors

Pathway		Exposure Parameters[a]				
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Soil[b]	Ingestion	100 mg/d	150	30	1E-06 kg/mg	--
	External	3 hr/d	150	30	1.14E-04 yr/hr	0.8
	Dermal	0.2 mg/cm^2-d	150	30	1E-6 kg/mg	5000 cm^2 ABS[c]
	Inhalation	10 m^3/d	150	30	1E-9 μg/kg	50 μg/m^3
Air[d]	Inhalation	10 m^3/d	150	30	--	--
Surface Water[e]	Boating External	3 hr/d	150	30	1.14E-4 yr/hr	0.5
Sediment[f]	Ingestion	100 mg/d	150	30	1E-6 kg/mg	--
	Dermal	0.2 mg/cm^2-d	150	30	1E-6 kg/mg	5000 cm^2
	External	3 hr/d	150	30	1.14E-4 yr/hr	0.2

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air are pCi/m^3.
e. Units for surface water concentration are pCi/L.
f. Units for sediment ar pCi/kg sediment.

Table 3.2: Hunter Scenario Exposure Factors

Pathway		Exposure Parameters[a]				
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Soil[b]	Ingestion	100 mg/d	70	30	1E-06 kg/mg	--
	External	4 hr/d	70	30	1.14E-04 yr/hr	0.8
	Dermal	0.2 mg/cm^2-d	70	30	1E-6 kg/mg	5000 cm^2 ABS[c]
	Inhalation	10 m^3/d	70	30	1E-9 kg/μg	50 μg/m^3
Air[d]	Inhalation	10 m^3/d	120	30	--	--
Biota[e]	Deer	15 g/d	365	30	1E-3 kg/g	0.13[e]
	Upland Birds	9 g/d	365	30	1E-3 kg/g	--
	Water fowl	35 g/d	365	30	1E-3 kg/g	--
Sediment[f]	Ingestion	300 mg/d	50	30	1E-06 kg/mg	--
	Dermal	0.2 mg/cm^2-d	50	30	1E-06 kg/mg	5000 cm^2 ABS
	External	4 hr/d	50	30	1.14E-4 yr/hr	0.2

a. Selection of exposure parameters is described in the text.
b. Units for soil concentration are pCi/kg dry soil.
c. ABS is the dermal absorption fraction for soil on skin (USEPA 1992).
d. Units for air concentration are pCi/m^3.
e. Units for biota concentration are pCi/kg wet weight.
f. Units for sediment ar pCi/kg sediment.

mg/cm^2-d (one contact event occurs per day). Contact occurs over a total surface area of 5,000 cm^2.

Sediment External Radiation Exposure The ranger is exposed to radiation emitted from the sediment while standing on the sediment. The rate of exposure is evaluated in a manner similar to that for standing on contaminated ground, except that a geometry/shielding factor of 0.2 is applied to account for the finite width of the shoreline. The exposure frequency is 150 days per year and one-third of the 9 hour work day. The daily exposure period is set to 3 hours representing the time distribution for the ranger.

3.2 Hunter

The hunter scenario involves an individual who hunts for game birds and animals on the site. The hunter is exposed while hunting to soil and air in upland regions, plus to shoreline sediment while hunting waterfowl, and from ingestion of birds and deer taken.

Exposure to contaminated soil occurs during hunting trips to the site. The number of trips is based on average hunter success rates for waterfowl (2 ducks per day) and upland game birds (0.5 pheasants per day) as published in annual harvest reports for the state of Washington Department of Fish and Wildlife (1992, 1993, 1994, and 1995). The total season take is set to 10 times the average hunter season take. For ducks this is about 100 birds and for pheasants it is about 25 birds. The hunter must make 50 trips hunting for each type of bird (50 to shoreline environments and 50 to upland areas). Each hunting trip involves 4 hours of on-site exposure with soil or sediment contact at the daily average value. The maximum number of days that could be spent hunting deer in a season is the length of the deer hunting seasons (bow, muzzleloader, and firearm). In state game management regions around Hanford (272, 278, 281, 284, 371, and 372) this is 48 days. However, it is unlikely that an individual hunter would spend the entire 48 days hunting. A reasonable maximum time of 20 days is used in the analysis, which is about half of the average hunting days to take a deer. The total time spent in upland areas (deer hunting plus upland game bird hunting) is 70 days per year.

Soil Ingestion The hunter is assumed to ingest soil inadvertently during time spent on-site and in the field. The entire daily intake (100 mg/d) is assumed to be related to the site.

Soil Dermal Contact Dermal contact is assumed to occur associated with the inadvertent soil ingestion pathway. Soil adheres to the skin at a rate of 0.2 mg/cm^2 per day (one contact event per day). Contact occurs over a total surface area of 5,000 cm^2.

Soil External Radiation Exposure The hunter is assumed to be on-site 4 hours per day in upland areas with exposure to soil occurring during that period. A shielding reduction factor of 0.8 is applied (as per HSRAM).

Soil Resuspension and Inhalation Resuspension of soil with subsequent inhalation is assumed to occur at all times while the hunter is on-site. The amount of resuspension is determined by use of the mass loading approach as described for the ranger scenario. The hunter is assumed to inhale a total of 10 m^3 of air during the 4 hours while on-site.

Air Inhalation While on-site, the hunter is potentially exposed to airborne contamination via inhalation. The individual is assumed to inhale a total of 10 m^3 of air during the 4 hours while on-site. The inhalation exposure occurs for all on-site activities and is included for the entire 4 hr/d.

Deer Ingestion One deer per season is assumed to be shot and eaten by the hunter and his family. (Elk are not included in this analysis because Hanford elk remain on the Fitzner-Eberhardt Arid Land Ecology reserve almost exclusively, with little travel across highway 240.) The deer is assumed to have a total weight of 45 kg, of which a 50% yield of deer meat is assumed for a total edible meat weight of 22.5 kg/deer. For an individual in the hunter family of four, the intake rate per individual (for one 45 kg deer) is 15 g/d. Because the hunting is assumed to continue over a period of 10 years, the hunter success rate of 19% is retained from the HSRAM scenarios.

Upland Game Bird Ingestion The upland game birds are assumed to be consumed by the hunter and family of four. The weight of meat from each bird is taken to be 0.5 kg (50% of a 1 kg bird). The total weight of upland game birds is 12.5 kg with consumption by a member of the hunter family of 9 g/d.

Waterfowl Ingestion The waterfowl are assumed to be consumed by the hunter and family of four. The weight of meat from each bird is taken to be 0.5 kg (50% of a 1 kg bird). The total weight of water fowl meat is 50 kg with consumption by each member of the hunter family of 35 g/d.

Sediment Ingestion Contact is assumed to occur with shoreline sediment while the hunter is involved in waterfowl and deer hunting along the Columbia River. The contact rate is assumed to be the same as for general soil contact. An intake of 100 mg/d is assumed for the time spent along the shore, which is the total daily intake.

Sediment Dermal Contact Dermal contact occurs along with sediment ingestion and is evaluated in the same manner as soil ingestion. Soil adheres to the skin at a rate of 0.2 mg/cm^2-d (one contact event occurs per day). Contact occurs over a total surface area of 5,000 cm^2.

Sediment External Radiation Exposure The hunter is exposed to radiation emitted from the sediment while standing on the sediment. The rate of exposure is evaluated in a manner similar to that for standing on contaminated ground, except that a geometry/shielding factor of 0.2 is applied to account for the finite width of the shoreline. The exposure frequency is 50 days per year and 4 hours per day.

3.3 Visitor Involved in River-Focused activities (boating, swimming, fishing)

This individual is included because many people currently use the Hanford Reach and adjacent wildlife refuge areas. Although there are a variety of year-round recreational activities, one of the most popular is sport fishing (Odegaard, 1994). The average angler catches salmon, steelhead, sturgeon and smallmouth bass. This individual may fish along the shoreline or from a motorized or non-motorized boat (DOA 1993). Fishing seasons in Washington are regulated by the Washington Department of Fish and Wildlife, and special rules and seasons are provided for trout, Salmon and sturgeon (WA 1995b).

Jet and propeller-driven boats are used along the entire Hanford Reach, while non-motorized boats generally stay in the vicinity of the three primitive river access areas: Vernita Bridge, White Bluffs Ferry Landing (east side only), and Ringold Hatchery. Public access to shorelines and islands is restricted, and no overnight camping is allowed within the Hanford Site. Recreational boating is only a day use activity. Data as to daily fishing and boating stay times per individual have not been determined. However, current parameters as reported in the HSRAM indicate that this individual may be potentially exposed 7 days per year averaged over a 70 year lifetime.

This report has not developed additional scenarios for the Visitor involved in River activities - the standard HSRAM Recreation Scenario (see Section 5) is used as a baseline. If the Hanford Reach is designated Wild and Scenic, the access to and use of the Reach would be likely to increase somewhat, and the 7 days/year exposure frequency for visitors might need to be increased.

4.0 Native American Exposure Scenarios

Disclaimer: The following material is a strawman or placeholder pending tribal review and modification.

Note: These scenarios have not received tribal review, and should not be used without approval by tribal technical staffs. A discussion of the government-to-government consultation process is not presented here (see Chatters, 1989 and Jacobs Engineering, 1995, for an introduction), nor is a discussion of concerns about treaty rights, natural resource trusteeship, the use of exposure and risk information in the decision process, or a discussion of culture-specific activities and plant and animal consumption rates (see CTUIR, 1995; Harris, 1993; numerous letters and reports prepared by the Hanford Site Nations). It must be stressed that THESE SCENARIOS ARE NOT APPROVED FOR SITE USE, but are presented solely as a starting point for discussion and research.

4.0 Introduction

The range of potential Native American activities on Site is very broad. They include activities specifically delineated in the Treaties, and also include a range of unlisted but reserved rights related to traditional lifestyles, and to preservation activities related to heritage (natural and cultural) resources. Specific activities (or activity categories) include hunting, gathering, collecting, fishing and processing of the catch along the shoreline, pasturing of livestock, fish hatchery working, as well as seasonal, ceremonial, social, educational, and trade activities, including a variety of unique activities, some of which have no standard suburban surrogate. Fish hatchery work (except for actual time spent on/in the River) is considered in the industrial worker scenarios; the other activities are intended to be included here.

Four semi-quantitative, but not necessarily all-inclusive scenarios were constructed to span the range of potential treaty-reserved activities:

- Full Subsistence (needed as a baseline and representing potential future uses)
- Hunting/Gathering/Fishing/Collecting/Pasturing Activities, without groundwater ingestion (referred to below as Hunting/Gathering)
- Cultural/Non-subsistence Activities, without groundwater ingestion
- Use of Columbia River islands for traditional activities.

The full subsistence scenario is intended to represent a reasonable set of activities that reflect a traditional lifestyle, with on-site activities occurring 180 days per year for life. This includes access to both the shoreline and to seeps/springs. Seep/spring water could be used for ingestion and biotic uptake directly from in situ groundwater, but it is assumed that irrigation would not occur (an unresolved issue). The Hunting/Gathering and Cultural/Non-subsistence scenarios basically split the Subsistence scenario into two activity sets: 150 days/year spent hunting/gathering/fishing and 30 days/year spent on non-food/medicine activities. These two scenarios assume that there is no groundwater access except via biotic uptake - seep/spring water ingestion is included in the river water ingestion. The person (hunter/gatherer) who visits the site to gather food and medicine is assumed to spend 100 days per year fishing, 25 days hunting and 25 days gathering (unapproved numbers used for discussion purposes only). While some of these activities are, in fact, gender-specific and age-specific, they are combined into a single activity set at present. A listing of specific activities conducted under food-related and non-food-related headings is not required for screening-level precision, but only an indication of the frequency of Site visits and similar information related to the degree of contact with environmental media. Further, specific information about particular plant species and other sensitive information is not useful, since the fate and transport models of contaminant movement through the biosphere may not at present provide a way to discriminate among species. Fate and transport models must be examined for their ability to handle information about species-specific biouptake and distribution among plant parts or animal tissues before justification exists for requesting sensitive information from tribal members.

Issues especially relevant to Native American scenarios:

1. The extent of on-Site groundwater/seep/spring use is unresolved at present. For the Subsistence scenario, full seep/spring access is assumed for ingestion but not irrigation; water ingestion rates would be divided between surface water and seep/spring water, as deemed appropriate by tribal technical staffs. For the other 2 scenarios, no seep/spring use is assumed except via biotic uptake, as the initial presumption.

2. Some activities might be expected to occur year-round, and some are seasonal in nature. Strawman parameters are shown below, but need to be reviewed by tribal technical staffs in consultation with tribal members. Related issues include peak exposures versus annual averages, gender and age-specific exposures, and others.

3. Different tribes have historically used the Hanford Reach to different degrees. The issue here is how to protect those tribes and individual members with high-end exposures, and how to determine to what degree full exercise of treaty-reserved rights imposes uneven exposure burdens on particular individuals or groups. The issue of high-end versus worst-case exposures needs to be addressed in a policy context as well as by uncertainty analysis. Current language used by EPA includes general (total population) best estimates of exposure, average exposures of the most sensitive segment of the general population, and either average or high-end exposures (unresolved) for population segments with subsistence-level exposures. In addition, the sensitive segments of the subsistence population (children, elders, women of child-bearing age) will need to be addressed.

4. Ethics and Equity issues will likely fall disproportionately on tribal communities as they are asked to accept decisions that have ramifications on their ability to exercise treaty-reserved rights. There are many issues that will need to be identified and discussed in open forums.

4.1 Full Subsistence (Baseline Unrestricted) Scenario

Note: This scenario has not received tribal approval for use on Site.

In this scenario, a person fully exercises treaty-reserved rights, and spends roughly half the year (180 days, 24 hours/day) on the site for the HSRAM-assumption of 30 years. Activities include hunting, gathering, collecting, fishing, and limited pasturing of livestock (pasturing of livestock for consumption is included here because human exposure could result, but pasturing of horses would be considered part of an ecological assessment because the horse is the ultimate receptor). Exposures related to these activities can occur both from ingestion as well as during gathering, preparation, and non-ingestion uses (Harris 1993, 1995). Additionally, exposures not related to nutrition could occur during other types of Site visits, such as religious, educational and other visits. Access to seep/spring water (for all uses except irrigation) and surface water are assumed, as is access to the shoreline. Preliminary assumptions and selection of exposure parameters are described below, and for the most part do not consider stratification of activities among age groups or by gender, although this clearly occurs. As with all of these scenarios, this section will require review and modification by tribal technical staffs before this scenario is used in any actual application.

Soil Ingestion. A person is assumed to continue a child's soil ingestion rate (200 mg/d) throughout life. A child's ingestion could be considered separately, since a child ingests more per body weight than adult. However, in this example the 6 (conventional) childhood years are not split out.

Soil Dermal Contact. Dermal contact is assumed to occur associated with the inadvertent soil ingestion pathway. Soil is assumed to adhere to the skin at a rate of 1 mg/cm^2 (compared to the 0.2 mg/cm^2 default value). Contact would occur over a skin surface area of 5,000 cm^2 (this is the default value and represents 25% of the total skin surface area). The skin absorption fraction (ABS) is pollutant-specific. The increased soil adherence rate needs to be reviewed for suitability for not only initial contact during, for instance, gathering of root crops, but also during cleaning and preparation.

Soil External Radiation Exposure. The person is assumed to be on-site 24 hours per day, and for this example is not divided among location types (shoreline, boating and upland). A shielding reduction factor of 0.8 is applied (as per HSRAM), which assumes that the person is standing on contaminated soil during the entire exposure period; this factor may need to be modified as appropriate, such as for activities such as gathering of root crops.

Soil Resuspension and Inhalation. This factor is identical to HSRAM. Resuspension of soil with subsequent inhalation is assumed to occur at all times while the person is on-site. The amount of resuspension is determined by use of the mass loading approach based on an ambient air mass loading value of 50 μg/m^3. The pollutant concentration in the particulate matter us assumed to be the same as the pollutant concentration in the soil. The person is assumed to inhale 20 m^3 of air during the 24 hours s/he is on-site (this is the default value).

Seep/spring Ingestion. For this scenario, the person is assumed to get half (1 L/d) his daily water intake from seep/spring water. The total of seep/spring water plus surface water ingestion equals the default value of 2 L/d; this ratio could be altered if appropriate. No decay of radionuclides between withdrawal of seep/spring water and ingestion is assumed, and no filtration of particulate matter (i.e. the concentration of contaminant in unfiltered seep/spring water is the appropriate comparison value unless determined to be otherwise appropriate).

Seep/spring Inhalation. The inhalation rate of 15 m^3/d represents volatilization of pollutants from seep/spring water into a relatively small space or short distance. It typically includes indoor activities such as showering and cooking; since these activities or analogues of these activities could be expected to occur during subsistence living, the default factor is included here. Rn222 is the only nuclide considered volatile (Strenge and Chamberlain, 1994).

Seep/spring Dermal Contact. One 10-minute shower per day (or an analogue of showering) is assumed, with a skin surface area of 20,000 cm^2; these are conventional default values, except that they occur for 180 days per year rather than 365.

Seep/spring External Radiation Contact. At present the MEPAS model does not include external radiation pathways for seep/spring water as it does for surface water. This may need to be added.

Air Inhalation. The person is assumed to inhale the default volume of air per day (20 m^3/d).

Surface Water Ingestion. For this scenario, the person is assumed to get half (1 L/d) his daily water intake from surface water and half from seep/spring water. While a person is expected to inadvertently ingest water during swimming (at a rate of 0.01 L/hr x 2.6 hr/swim), this is not expected to add significantly to his total daily water intake. Swimming-specific exposures can be pulled out of the surface water exposures and evaluated separately if desired.

Surface Water Inhalation. The person is assumed to inhale near-surface volatiles while swimming 2.6 hours each of 70 days during the year. The volume of air (15 m^3/day) may need to be split among seep/spring water and surface water inhalation routes, since this is the conventional full-day volatile inhalation default value.

Surface Water (swimming) Dermal Contact. The dermal contact during swimming assumed 2.6 hours of swimming for 70 days, with a total skin surface contact area of 20,000 cm^2. The absorption coefficient is pollutant specific.

Surface Water External Radiation Exposure. Swimming and boating are each assumed to occur for 2.6 hours/day for 70 days/year, and shoreline use is assumed to occur for 24 hours/day for 180 days/year. During boating, the boat is assumed to shield the person from half of the radiation coming from the surface water.

Shoreline Sediment Ingestion. Contact is assumed to occur daily since most of the on-site activity is directed toward river-based resources and activities. The sediment ingestion rate is the same as that for soil, and is in addition to it; it may be appropriate to split the 200 mg/day intake rate between soil and sediment.

Shoreline Sediment Dermal Contact. This pathway is similar to the surface soil dermal pathway, and it may be appropriate to split exposure time between them.

Shoreline Sediment External Radiation Exposure. The person is exposed to radiation emitted from the sediment while standing on the shoreline.

Other Unique Exposure Pathways. Particular activities, such as sweat bathing and smudging, will need to be added. These can be parameterized into the equations provided in Section 6; activities can be disaggregated into their component pathways. Details regarding culturally-sensitive practices may be then reaggregated into lumped exposure parameters. This approach may be expanded to include direct exposure to cultural materials and/or dermal absorption from contact from cultural materials.

Food Ingestion Rates. Food ingestion parameters were adjusted upward from HSRAM by assuming that 75% of plant material ingested is of local origin, and 100% of fish ingestion is of local origin. HSRAM (Rev. 3) includes all types of plants within general fruit (42 g/d) and vegetable (80 g/d) categories, rather than subdividing plant types into root, vine, leafy, fruit and grass/pasture. Strenge and Chamberlain (1994) further indicate that current Hanford models use a single set of contaminant-specific uptake factors that does not distinguish among plant species or classes, plant types, or plant parts, so that there is, in effect, a single overall vegetable-matter ingestion rate of 122 g/d per person in HSRAM, which is increased here to 250 g/d based on 75% local origin. It will not be useful to investigate specific ingestion rates of roots, fruits, and so on unless uptake factors to specific plant parts (roots versus leaves) or specific plant species are available. Each risk assessment application should be reviewed for the ability of the fate and transport models to provide the level of detail needed for the assessment context.

The HSRAM value for meat intake (75 g/d) plus game (1 g/d) is collapsed into a single meat consumption rate. The waterfowl and upland game bird consumption rates are assumed to be the same for subsistence as they are for recreational hunting; this needs to be reviewed for seasonal take, length of season and special hunting privileges, and so on. Again, since contaminant concentration among animal/fowl species is currently modeled solely on the basis of proportional animal body weight, it will not be useful to determine consumption rates of specific species or animal organs/tissues unless information about contaminant uptake and tissue distribution is available.

A fish consumption rate of 270 g/d (10-fold higher than HSRAM) is a rough estimate of a high-end consumption rate (CRITFC, 1994), but is likely to be well below traditional subsistence levels (U.S. Department of the Interior, 1942; Hunn, 1990; R Jim, S Harris and others, personal communication).

Exposure of Biota to Contaminants. The amount of contaminants predicted to occur in plants or animals depends to a large extent on the choice of the contaminant fate and transport model. Vegetation can be exposed via uptake from soil, seep/spring water, and surface water, as well as through particulate deposition on leaf surfaces. Fauna in turn ingest different plants through grazing, browsing, seed ingestion, and so on. Methods for environmental fate and transport will need to be reviewed for each specific application in order to determine whether it is appropriate to subdivide the generic plant, generic animal and generic fish into more categories. Some factors (a very incomplete list) to consider are: particle size and particulate deposition rates, immersion of plants in air vapor, environmental uptake ratios and bioconcentration factors, applicability of radionuclide decay during water system retention, loss of pollutants to evaporation during irrigation, harvest and preparation of plant materials, applicability of contaminant loss during preparation of fish and animals, root uptake and translocation within the plant, interception of airborne particulates during particulate deposition, weathering time, deposition rates onto pasture, soil to feed uptake, soil ingestion while on pasture, feed to cattle uptake, feed to cow's milk uptake, animal air and water intake rates, and so on. As indicated previously, the total dose to the plant or animal from all contaminants through all pathways is the objective.

Table 4-1: Native American Subsistence Scenario Exposure Factors

Pathway		Exposure Parameters				
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Soil	Ingestion[a]	200 mg/d	180	30	1E-6 kg/mg	--
	External	24 hr/d	180	6 (C) 24 (A)	1.14E-04 yr/hr	0.8
	Dermal	1 mg/cm^2-d	180	30	1E-6 kg/mg	5000 cm^2 ABS
	Inhalation[b]	20 m^3/d	180	30	1E-9 kg/µg	50 $\mu g/m^3$
Air	Inhalation	20 m^3/d	180	30	--	--
Seep/Spring water	Ingestion[c]	1 L/d	180	30	--	--
	Inhalation[d]	15 m^3/d	180	30	--	0.1 L/m^3
	Dermal[e]	0.17 hr/d	180	30	1E-3 L/cm^3	20,000 cm^2 K_p
Surface Water	Ingestion[f]	1 L/d	180	30	--	--
	Inhalation	15 m^3/d	180	30	--	0.1 L/m^3
	Dermal[g]	2.6 hr/d (swimming)	70	30	1E-3 L/cm^3	20,000 cm^2 K_p
Biota[h]	Fish[i]	270 g/d	365	30	1E-3 kg/d	--
	Fruit and vegetation	250 g/d	365	30	1E-3 kg/d	--
	Meat[j]	75 g/d	365	30	1E-3 kg/d	--
	Upland Birds	9 g/d	365	30	1E-3 kg/g	
	Waterfowl	35 g/d	365	30	1E-3 kg/d	--
Sediment	Ingestion	200 mg/d	180	30	1E-06 kg/mg	--
	Dermal	1 mg/cm^2-d	180	6 (C) 24 (A)	1E-6 kg/mg	5000 cm^2 ABS
	External	12 hr/d	180	30	1.14E-4 yr/hr	0.2
Other unique pathways[k]						

Table 4-1: Native American Subsistence Scenario Exposure Factors

Pathway	Exposure Parameters
a.	Soil ingestion is typically separated into child (200 mg/d) and adult (100 mg/d) factors, but considering the activities included in these scenarios, it seems reasonable to assume that the higher rate would persist throughout a lifetime.
b.	Soil inhalation is the same as dust resuspension and inhalation.
c.	Ingestion of seep/spring water + surface water should equal 2 L/d, distributed among them as appropriate; in this example they are distributed equally.
d.	In HSRAM, groundwater use is a household scenario where inhalation comes from volatilization during showering and other household use. To the extent that analogous activities occur, this factor should be retained, possibly reducing the exposure frequency (days/year or hours/day).
e.	The dermal factor for groundwater pathways in HSRAM reflects bathing. For this example, it was assumed that seep/spring water is used for bathing 180 days/yr and surface water for swimming 70 d/yr.
f.	As for seep/spring water, exposures may still occur that are equivalent of suburban household exposures.
g.	For surface water, only swimming (2.6 hr/d) is included.
h.	Foodchain pathways include deposition, soil uptake and seep/spring water uptake, as well as aquatic pathways. There are also additional factors relevant to human ingestion, such as additional plant parts used or eaten (and multiple parts per plant that rotate through the seasons), medicinal uses (infusions, teas, poultices, etc.), other potential contact with people or their foods (food storage basketry, sleeping mats, extensive contact during basketmaking, use of bones, feathers and sinews, and many other things. Fate and transport models need to be examined for foodchain and other exposure methods prior to application.
i.	Note that fish consumption should include multiple species and parts eaten.
j.	The suburban meat consumption rate is 74 g/d plus 1 g/d of game; these are added together here.
k.	Other unique pathways (e.g. volatilization of contaminants from water during sweat bathing, inhalation of cooking fire smoke) need to be included as appropriate if they contribute to total exposure.

4.2 Combined Indirect Pathways Scenario (Hunting, gathering, collecting, fishing)

Note: This scenario has not received tribal approval for use on Site.

This scenario is a subset of the subsistence pathway that contains only the pathways related to foods and medicines. This person is assumed to be on-site for 150 days per year, of which 100 are spent fishing, 25 hunting and 25 gathering/collecting. Shoreline access is assumed, and these activities remain at the 24 hr/d duration for 30 years. These frequencies will need to be reviewed by tribal technical staffs; they are intended to represent a reasonable but less-than-subsistence usage level. The most significant difference is that no direct seep/spring water access is assumed, and therefore seep/spring contamination can only reach the person through the foodchain.

4.3 Non-Subsistence Cultural Activities

Note: This scenario has not received tribal approval for use on Site.

This scenario is the other portion of the subsistence scenario, and is intended to include on-site access for 30 days/year separate from gathering and ingesting foods and medicines. The types of activities intended to be addressed here include religious, ceremonial, educational, and similar activities. However, to the extent that some of these activities may require the special collection and/or ingestion of plant or animal material (or water), some ingestion may need to be included in this scenario. No confidential information is expected to be needed; even though actual locations may have identifiable contaminant concentrations, it is sufficient for these semi-quantitative applications to estimate what fraction of a person's time might be spent in a general area.

4.4 Columbia River Island User

Discrete radioactive particles have been found on islands and along the shores of the Columbia River (Sula 1980). These were identified as of concern to dose (Napier et al. 1995).

A credible worst-case exposure scenario was developed in a meeting concerning D-Island held June 7, 1995. It is based on Native American traditional uses of the island involving extended occupation and use of the island as a base for fishing or other traditional uses. In the following analyses, it is assumed with a probability of 1.0 that the island is visited; all calculations begin with the assumption that a person is on the island.

Within the basic scenario, several pathways are evaluated. These include inhaling a particle, ingesting a particle (during incidental ingestion of small amounts of sediments), direct external exposure without contact, and getting a particle lodged on the skin.

The time spent on the island is important in calculating the likelihood that a person will interact with a particle. For the analyses, a distribution of times is used. The distribution used assumes an individual spends a minimum of 4 hours and a maximum of 40 days is spent on the island every year. The most likely value is 2 days.

Table 4.2: Native American Hunting/Gathering Scenario Exposure Factors

Pathway		Exposure Parameters				
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg/d	150	30	1E-6 kg/mg	--
	External	24 hr/d	150	30	1.14E-04 yr/hr	0.8
	Dermal	1 mg/cm²-d	150	30	1E-6 kg/mg	5000 cm² ABS
	Inhalation	20 m³/d	150	30	1E-9 kg/μg	50 μg/m³
Air	Inhalation	20 m³/d	150	30	--	--
Groundwater	Ingestion	N/A	--	--	--	--
	Inhalation	N/A	--	--	--	--
	Dermal	N/A	--	--	--	--
Surface Water	Ingestion	1 L/d	100	30	--	--
	Dermal	2.6 hr/d	50	30	1E-3 L/cm³	20,000 cm² K_p
Biota	Fish	230 g/d	365	30	1E-3 kg/g	--
	Fruit and vegetation	250 g/d	365	30	1E-3 kg/g	--
	Game	75 g/d	365	30	1E-3 kg/g	--
	Upland Birds	9 g/d	365	30	1E-3 kg/g	--
	Waterfowl	35 g/d	365	30	1E-3 kg/g	--
Sediment	Ingestion	200 mg/d	100	30	1E-06 kg/mg	--
	Dermal	1 mg/cm²-d	100	30	1E-6 kg/mg	5000 cm² ABS
	External	12 hr/d	100	30	1.14E-4 yr/hr	0.2
Other unique pathways						
Notes: see Table 4.1						

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Table 4.3: Native American Cultural Activities Scenario Exposure Factors

Pathway		Exposure Parameters						
Media	Exposure Route	Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg/d	30	30	70(A)	30 x 365	1E-6 kg/mg	--
	Dermal	1 mg/cm^2-d	30	6(C) 24(A)	16(C) 70(A)	30 x 365	1E-6 kg/mg	2500 cm^2(C) 5000 cm^2(A) ABS
	Inhalation	10 m^3/d	30	30	70	30 x 365	1E-9 kg/µg	50 µg/m^3
Air	Inhalation	20 m^3/d	30	30	70	30 x 365	--	--
Other unique pathways							--	--

Notes: see Table 4.1

Table 4.4 Constants used in the analyses

Constant	Value	Units
Sediment ingestion rate	200	mg/day
Ingestion dose factor	3.77	rem/pCi
Ingestion slope factor	6.73E-6	pCi^{-1}
Co-60 Half-life	5.27	years
Lifetime	70	years
Dust loading	0.1	mg/m^3
Breathing rate	20	m^3/day
Soil density	1500	mg/cm^3

Standard values are provided for uptake of soil onto skin (DOE 1994); a skin loading of 0.2 mg/cm^2 is used. However, a distribution of the retention time of the soil on the skin is used. Soil is assumed to remain on the skin from 0 to 48 hours, in a triangular distribution with a most likely value of 2 hours. Exposed skin area is assumed to be at least 5000 cm^2, and range uniformly up to the total skin area of 15,000 cm^2. Other exposure parameters used are set as constants at the HSRAM (DOE 1994) approved, usually conservative, values shown in Table 1. Particle activities and particle densities are as described above. The particle activity is described as a lognormal distribution with a median of 2.3 μCi and a geometric standard deviation of 2.8. In some instances, the value of the average particle activity is needed; it is taken to be 2.3, with a normal distribution with a standard deviation of 10%. The particle density in the rocky areas is assumed to lie uniformly between 5×10^{-8} per m^3 and 1×10^{-6} per m^3. In the sandy areas, it is assumed to range from the same low, 5×10^{-8}, to as high as 4×10^{-6}.

No credit is assumed for shielding from direct irradiation.

4.4.1 Exposure equations A series of equations were established to describe the individual exposure pathways. These equations differ from the more general ones presented in Section 6.

For the likelihood of being subjected to a skin lesion/beta particle burn, the equation is

> (Probability of picking up a particle on the skin/day) * (Number of days on the island/year) * (Particle activity) * (Time on the skin).

For external irradiation without direct contact, the equation is

> (Time spent on island) * (Particle density) * (Slope factor) * (Decay integral)

The decay integral is required in this calculation because the slope factor is defined for constant exposure over a lifetime. Thus, the scenario assumes that the individual is exposed every year of his life. Because the cobalt-60 has a 5.27 year half-life, the exposures decrease rapidly, and this must be accounted for in the exposure estimate.

For the possibility of ingestion of a particle, the equation is

> (Ingestion rate, g/day) * (Concentration, uCi/g) * (Time on island, days) * (Ingestion slope factor) * (Decay integral)

The scenario is established for a lifetime of exposure, so the annual exposures are multiplied by the integral of the activity over a 70 year lifetime.

For inhalation, the equation is based on lodging of a discrete particle in the nose, as

> (Inhalation rate, g/day) * (Time on island, days) * (Particle density, g^{-1}) * (Particle activity, μCi) * (Retention time in nose)

The possibility of inhaling a discrete radioactive particle was addressed by Durham and Soldat in the appendix of Cooper and Woodruff (1993). They found that the physical size of the particles was such that it was not possible to inhale one into the lungs, but that they would, at worst, lodge in the anterior portion of the nose. Durham used the specific activity of hot particles commonly found in the commercial nuclear industry in his calculation (60,000 Ci/cm^3). This specific activity relates to relatively "young" particles; those found in the Columbia River from plutonium production activities are at least 25 years old. Thus, for the same particle activity, the particles would physically be much larger than assumed by Durham. (He based his calculations on a 10 micron particle.) The typical size found by Sula is 0.1 mm (100 microns). Thus, the nasal retention used by Durham (1 to 2 days) is considerably longer than what would occur with this size particle. However, a retention of up to 2 days has been used in this analysis.

5.0 General Scenarios

For this report, the HSRAM Recreational scenario is included without modification for comparison. Eventually, Hanford-specific information might be used to modify the exposure factors. HSRAM-specified parameters for this scenario are provided in Table 5.1.

For this report, the HSRAM Residential scenario is included. In order to accommodate potential irrigation with river water, irrigation of fruits and vegetables is included at a rate of 45 inches per year. No groundwater pathways are to be included in applications off of the Hanford Site. HSRAM-specified parameters for this scenario are provided in Table 5.2.

For this report, the HSRAM Agricultural scenario is included. In order to accommodate potential irrigation with river water, irrigation of fruits and vegetables is included at a rate of 45 inches per year. No groundwater pathways are to be included in applications off of the Hanford Site. HSRAM-specified parameters for this scenario are provided in Table 5.3.

Table 5.1: HSRAM Recreational Scenario Exposure Factors

Pathway		Exposure Parameters				
Media	Exposure Route	Intake Rate[a]	Exposure Frequency[b] (d/yr)	Exposure Duration[a] (yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg/d (C) 100 mg/d (A)	7	6 (C) 24 (A)	1E-03 g/mg	--
	External	8 hr/d	7	30	1.14E-04 yr/hr	0.8[c]
Air	Inhalation	20 m^3/d	7	30	--	--
Groundwater	Ingestion	2 L/d[b]	7	30	--	--
Surface Water	Ingestion	2 L/d[b]	7	30	--	--
Sediment[g]	Ingestion	200 mg/d (C) 100 mg/d (A)	7	6 (C) 24 (A)	1E-03 g/mg	--
Biota	Waterfowl	--	--			
	Game	1 g/d[h]	365	30	--	0.19[f]
	Fish	54 g/d[i]	365	30	--	0.5[g]
	Plants	--	--	--	--	--

a Parameters recommended in EPA 1991, except as noted.
b Site-specific parameter; see text for additional information.
c Dose reduction factor (unitless; EPA 1991).
d Indoor inhalation rate (EPA 1991); evaluated only for radon-222.
e Venison fat consumption rate based on 45 kg deer per family per year (Paustenbach 1989)
f Intake adjusted for upperbound mean deer hunter success rate of 19% for game management unit 370
h WAC 173-340-730.
C = Child
A = Adult

Table 5.2: HSRAM Residential Scenario Exposure Factors

Pathway		Exposure Parameters				
Media	Exposure Route	Intake Rate[a]	Exposure Frequency[b] (d/yr)	Exposure Duration[a] (yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg/d (C) 100 mg/d (A)	365	6 (C) 24 (A)	1E-03 g/mg	–
	External	24 hr/d[c]	365	30	1.14E-04 yr/hr	0.8[d]
Air	Inhalation	20 m^3/d	365	30	–	–
Groundwater	Ingestion	2 L/d[b]	365	30	–	–
	Inhalation	15 m^3/d[e]	365	30	–	0.1 L/m^3[f]
Surface Water	Ingestion	2 L/d[b]	365	30	–	–
	Inhalation	15 m^3/d[e]	365	30	–	0.1 L/m^3[f]
Sediment[g]	Ingestion	200 mg/d (C) 100 mg/d (A)	7[c]	6 (C) 24 (A)	1E-03 g/mg	–
Biota	Fish	54 g/d[h]	365	30	–	0.5[j]
	Fruit	42 g/d[i]	365	30	–	–
	Vegetable	80 g/d[i]	365	30	–	–

a Parameters recommended in EPA 1991, except as noted.
b Parameters recommended in WAC 173-340-720, WAC 173-340-740, or WAC 173-340-750, Method B, except as noted.
c Site-specific parameter; see text for additional information.
d Dose reduction factor (unitless; EPA 1991).
e Indoor inhalation rate (EPA 1991); evaluated only for radon-222.
f 0.0001 x 1,000 L/m^3 (Andelman 1990).
g Parameter recommended in EPA-10 1991.
h WAC 173-340-730.
i EPA 1991; note: based on wet weight.
C = Child
A = Adult

Table 5.3: HSRAM Agricultural Scenario Exposure Factors

Pathway		Exposure Parameters				
Media	Exposure Route	Intake Rate[a]	Exposure Frequency[b] (d/yr)	Exposure Duration[a] (yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg/d (C) 100 mg/d (A)	365	6 (C) 24 (A)	1E-03 g/mg	--
	External	24 hr/d[c]	365	30	1.14E-04 yr/hr	0.8[d]
Air	Inhalation	20 m^3/d	365	30	--	--
Groundwater	Ingestion	2 L/d[b]	365	30	--	--
	Inhalation	15 m^3/d[e]	365	30	--	0.1 L/m^3[f]
Surface Water	Ingestion	2 L/d[b]	365	30	--	--
	Inhalation	15 m^3/d[e]	365	30	--	0.1 L/m^3[f]
Sediment[g]	Ingestion	200 mg/d (C) 100 mg/d (A)	7[c]	6 (C) 24 (A)	1E-03 g/mg	--
Biota	Dairy	300 g/d	365	30	--	--
	Beef	75 g/d	365	30	--	--
	Game	1 g/d[h]	365	30	--	0.19[i]
	Fish	54 g/d[j]	365	30	--	0.5[j]
	Fruit	42 g/d[k]	365	30	--	--
	Vegetable	80 g/d[k]	365	30	--	--

a Parameters recommended in EPA 1991, except as noted.
b Parameters recommended in WAC 173-340-720, WAC 173-340-740, or WAC 173-340-750, Method B, except as noted.
c Site-specific parameter; see text for additional information.
d Dose reduction factor (unitless; EPA 1991).
e Indoor inhalation rate (EPA 1991); evaluated only for radon-222.
f 0.0001 x 1,000 L/m^3 (Andelman 1990).
g Parameter recommended in EPA-10 1991.
h Venison fat consumption rate based on 45-kg deer per family per year (Paustenbach 1989).
i Intake adjusted for upperbound hunter success rate of 19% for game management unit 370.
j WAC 173-340-730.
k EPA 1991; note: based on wet weight.
C = Child
A = Adult

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6.0 Exposure and Intake Equations

The following equations are adapted and expanded from those in Appendix D of the Hanford Site Risk Assessment Methodology (HSRAM) (DOE 1995). The same notation and terminology is used for consistency with this reference for these standard equations. Additions have been made to the equations to make them more directly applicable to scenarios related to exposure to contaminants in the vicinity of the Columbia River.

6.1 External Dose from Radionuclides

$$Dose_{ext} = ((C_{soil} \times ET_{soil} \times RF_{soil} \times EF_{soil} + C_{sed} \times ET_{sed} \times EF_{sed}) \times DF1 +$$

$$C_{river} \times ET_{swim} \times EF_{swim} \times DF2 + C_{river} \times ET_{boat} \times EF_{boat} \times DF3 +$$

$$\Sigma (C_{items} \times ET_{items} \times EF_{items} \times DF4)) \times ED$$

where

$Dose_{ext}$	=	external dose from radionuclide (rem)
C_{soil}	=	radionuclide concentration in soil (pCi/g)
C_{sed}	=	radionuclide concentration in sediment (pCi/g)
C_{river}	=	radionuclide concentration in river water (pCi/L)
C_{items}	=	radionuclide concentrations in cultural items (pCi/g) - an example might be woven mats made of contaminated reeds
DF1	=	dose conversion factor for soils and sediments (rem/hr per pCi/g)
DF2	=	dose conversion factor for swimming (rem/hr per pCi/L)
DF3	=	dose conversion factor for boating (rem/hr per pCi/L)
DF4	=	dose conversion factor for contact with small items (rem/hr per pCi/g)
ET_{soil}	=	exposure time for soils (hr/day)
ET_{sed}	=	exposure time for sediments (hr/day)
ET_{swim}	=	exposure time for swiming (hr/day)
ET_{boat}	=	exposure time for boating (hr/day)
ET_{items}	=	exposure frequency for each cultural item (hr/day)
EF_{soil}	=	exposure frequency for soils (day/yr)
EF_{sed}	=	exposure frequency for sediments (day/yr)
EF_{swim}	=	exposure frequency for swiming (day/yr)
EF_{boat}	=	exposure frequency for boating (day/yr)
EF_{items}	=	exposure frequency for each cultural item (day/yr)
RF_{soil}	=	soil shielding factor (dimensionless)
ED	=	exposure duration (years)

If the exposures of children are significantly different from adults, it may be desirable to apply this equation twice - once for the 0-6 year age group and once for the adult age group. Separate estimates of the exposure times and exposure frequencies would be required.

6.2 Dermal Exposures (Carcinogenic and Non-carcinogenic, Non-radioactive)

$$DAD = (C_{soil} \times AF_{soil} \times ABS \times SA_{soil} \times EF_{soil} \times CF1 +$$

$$C_{sed} \times AF_{sed} \times ABS \times SA_{sed} \times EF_{sed} \times CF1 +$$

$$\Sigma\,(C_{other} \times AF_{other} \times ABS \times SA_{other} \times ET_{other} \times EF_{other} \times CF2) +$$

$$C_{seep} \times K_p \times SA_{seep} \times ET_{seep} \times EF_{seep} \times CF3 +$$

$$C_{river} \times K_p \times SA_{river} \times ET_{river} \times EF_{river} \times CF3) \times ED/(BW \times AT)$$

where

DAD	=	Dermally absorbed dose (mg/kg-d)
C_{soil}	=	Contaminant soil concentration (mg/kg)
S_{sed}	=	Contaminant sediment concentration (mg/kg)
C_{other}	=	Contaminant concentration in cultural materials (mg/kg) - examples might include ashes or pigments
C_{seep}	=	Contaminant concentration in seep/spring water (mg/L)
C_{river}	=	Contaminant concentration in river water (mg/L)
AF_{soil}	=	Adherence factor for soil (mg/cm^2-day)
AF_{sed}	=	Adherence factor for sediment (mg/cm^2-day)
AF_{other}	=	Adherence factor for cultural materials (mg/cm^2-day)
ABS	=	material-specific absorption factor (unitless)
SA_{soil}	=	Body surface area exposed to soils (cm$^{2)}$
SA_{sed}	=	Body surface area exposed to sediments (cm$^{2)}$
SA_{other}	=	Body surface area exposed to cultural materials (cm$^{2)}$
SA_{seep}	=	Body surface area exposed to seep/spring water (cm$^{2)}$
SA_{river}	=	Body surface area exposed to river water (cm$^{2)}$
EF_{soil}	=	Exposure frequency to soils (day/yr)
EF_{sed}	=	Exposure frequency to sediments (day/yr)
EF_{other}	=	Exposure frequency to cultural materials (day/yr)
EF_{seep}	=	Exposure frequency to seep/spring water (day/yr)
EF_{river}	=	Exposure frequency to river water (day/yr)
ET_{seep}	=	Exposure time to seep/spring water (hr/day)
ET_{river}	=	Exposure time to river water (hr/day)
ET_{other}	=	Exposure time to cultural materials (hr/day)
K_p	=	permeability coefficient for a chemical in water through skin (cm/hr)
CF1	=	Units conversion factor (1E-6 kg/mg)
CF2	=	Units conversion factor (1E-6 kg/mg / 24 hr/day)
CF3	=	Units conversion factor (1E-3 L/cm^3)
ED	=	Exposure duration (yr)
BW	=	Body weight (kg)
AT	=	Averaging time (yr x 365 day/yr)

This equation should be applied twice - once for children age 0-6 and once for adults, and the results summed.

6.3 Inhalation (Non-radioactive)

$$INH = (C_{soil} \times ML \times ET_{soil} \times EF_{soil} + C_{seep} \times VF \times ET_{seep} \times EF_{seep} + C_{river} \times VF \times ET_{river} \times EF_{river} + C_{other} \times CF_{other} \times ET_{other} \times EF_{other}) \times ED \times IR / (BW \times AT)$$

where

INH	=	Chronic daily inhalation intake (mg/kg-day)
C_{soil}	=	Contaminant concentration in soil (mg/kg)
C_{seep}	=	Contaminant concentration in seep/spring water (mg/L)
C_{river}	=	Contaminant concentration in river water (mg/L)
C_{other}	=	Contaminant concentration in other airborne material (mg/kg) - examples might include wood smoke from fires or smoke from ceremonial burning
ML	=	Mass loading of soil (PM_{10}) in air (g/m^3)
ET_{soil}	=	Exposure time for breathing resuspended dusts (hr/day)
ET_{seep}	=	Exposure time for breathing volatilized seep/spring water (hr/day)
ET_{river}	=	Exposure time for breathing volatilized river water (hr/day)
ET_{other}	=	Exposure time for breathing materials suspended from cultural activities (hr/day)
EF_{soil}	=	Exposure frequency for exposure to resuspended dusts (day/yr)
EF_{seep}	=	Exposure frequency for exposure to volatilized seep/spring water dusts (day/yr)
EF_{river}	=	Exposure frequency for exposure to volatilized river water (day/yr)
EF_{other}	=	Exposure frequency for exposure to materials resuspended from cultural activities (day/yr)
VF	=	Volatilization factor (L/m^3)
CF_{other}	=	Factor relating cultural materials to air concentration, probably dependent on material type (e.g., soil product, vegetation product) (g/m^3)
IR	=	Inhalation rate (m^3/d)
ED	=	Exposure duration (yr)
BW	=	Body weight (kg)
AT	=	Averaging time (yr x 365 day/yr)

If there are significant age-related differences, this equation may need to be applied to children and adults separately and the results summed.

6.4 Inhalation (radioactive)

$$Dose_{inh} = (C_{soil} \times ML \times ET_{soil} \times EF_{soil} + C_{seep} \times VF \times ET_{seep} \times EF_{seep} +$$

$$C_{river} \times VF \times ET_{river} \times EF_{river} + C_{other} \times CF_{other} \times ET_{other} \times EF_{other}) \times$$

$$ED \times IR \times DF5$$

where

$Dose_{inh}$	=	Inhalation dose from radionuclide (rem)
C_{soil}	=	Radionuclide concentration in soil (pCi/g)
C_{seep}	=	Radionuclide concentration in seep/spring water (pCi/L)
C_{river}	=	Radionuclide concentration in river water (pCi/L)
C_{other}	=	Radionuclide concentration in other airborne material (pCi/g) - examples might include wood smoke from fires or smoke from ceremonial burning
ML	=	Mass loading of soil (PM_{10}) in air (g/m^3)
ET_{soil}	=	Exposure time for breathing resuspended dusts (hr/day)
ET_{seep}	=	Exposure time for breathing volatilized seep/spring water (hr/day)
ET_{river}	=	Exposure time for breathing volatilized river water (hr/day)
ET_{other}	=	Exposure time for breathing materials suspended from cultural activities (hr/day)
EF_{soil}	=	Exposure frequency for exposure to resuspended dusts (day/yr)
EF_{seep}	=	Exposure frequency for exposure to volatilized seep/spring water dusts (day/yr)
EF_{river}	=	Exposure frequency for exposure to volatilized river water (day/yr)
EF_{other}	=	Exposure frequency for exposure to materials resuspended from cultural activities (day/yr)
VF	=	Volatilization factor (L/m^3)
CF	=	Factor relating cultural materials to air concentration, probably dependent on material type (soil product, vegetation product)
IR	=	Inhalation rate (m^3/d)
ED	=	Exposure duration (yr)
DF5	=	Inhalation dose factor (rem/pCi)

If there are significant age-related differences, this equation may need to be applied to children and adults separately and the results summed.

6.5 Ingestion (non-radioactive)

$$ING = (C_{soil} \times IR_{soil} + C_{sed} \times IR_{sed} + C_{river} \times IR_{river} + C_{seep} \times IR_{seep} +$$

$$C_{fish} \times IR_{fish} + C_{leafy} \times IR_{leafy} + C_{root} \times IR_{root} + C_{meat} \times IR_{meat} +$$

$$C_{milk} \times IR_{milk} + C_{eggs} \times IR_{eggs} + C_{bird} \times IR_{bird}) \times EF \times ED/(AT \times BW)$$

where

ING	=	Chronic daily ingestion rate (mg/kg-day)
C_{soil}	=	Concentration of contaminant in soil (mg/kg)
C_{sed}	=	Concentration of contaminant in sediment (mg/kg)
C_{river}	=	Concentration of contaminant in river water (mg/kg)
C_{seep}	=	Concentration of contaminant in seep/spring water (mg/kg)
C_{fish}	=	Concentration of contaminant in fish (mg/kg)
C_{leafy}	=	Concentration of contaminant in above-ground vegetation (mg/kg)
C_{root}	=	Concentration of contaminant in root vegetables (mg/kg)
C_{meat}	=	Concentration of contaminant in meat (mg/kg)
C_{milk}	=	Concentration of contaminant in milk (mg/kg)
C_{eggs}	=	Concentration of contaminant in eggs (mg/kg)
C_{bird}	=	Concentration of contaminant in domestic and wild birds (mg/kg)
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{sed}	=	Ingestion rate of sediment (kg/day)
IR_{river}	=	Ingestion rate of river water (kg/day)
IR_{seep}	=	Ingestion rate of seep/spring water (kg/day)
IR_{fish}	=	Ingestion rate of fish (kg/day)
IR_{leafy}	=	Ingestion rate of above-ground vegetation (kg/day)
IR_{root}	=	Ingestion rate of root vegetables (kg/day)
IR_{meat}	=	Ingestion rate of meat (kg/day)
IR_{milk}	=	Ingestion rate of milk (kg/day)
IR_{eggs}	=	Ingestion rate of eggs (kg/day)
IR_{bird}	=	Ingestion rate of domestic and wild birds (kg/day)
EF	=	Exposure frequency (day/yr)
ED	=	Exposure duration (yr)
AT	=	Averaging time (yr x 365 day/yr)
BW	=	Body weight (kg)

This equation should be applied twice - once for children age 0-6 and once for adults, and the results summed.

Each of the concentration values may need to be estimated from a basic environmental measurement using concentration ratios, bioaccumulation factors, or other related techniques.

6.6 Ingestion (radioactive)

$$Dose_{ing} = (C_{soil} \times IR_{soil} + C_{sed} \times IR_{sed} + C_{river} \times IR_{river} + C_{seep} \times IR_{seep} + C_{fish} \times IR_{fish} + C_{leafy} \times IR_{leafy} + C_{root} \times IR_{root} + C_{meat} \times IR_{meat} + C_{milk} \times IR_{milk} + C_{eggs} \times IR_{eggs} + C_{bird} \times IR_{bird}) \times EF \times ED \times CF \times DF6$$

where

$Dose_{ing}$	=	Ingestion dose (rem)
C_{soil}	=	Concentration of radionuclide in soil (pCi/g)
C_{sed}	=	Concentration of radionuclide in sediment (pCi/g)
C_{river}	=	Concentration of radionuclide in river water (pCi/g)
C_{seep}	=	Concentration of radionuclide in seep/spring water (pCi/g)
C_{fish}	=	Concentration of radionuclide in fish (pCi/g)
C_{leafy}	=	Concentration of radionuclide in above-ground vegetation (pCi/g)
C_{root}	=	Concentration of radionuclide in root vegetables (pCi/g)
C_{meat}	=	Concentration of radionuclide in meat (pCi/g)
C_{milk}	=	Concentration of radionuclide in milk (pCi/g)
C_{eggs}	=	Concentration of radionuclide in eggs (pCi/g)
C_{bird}	=	Concentration of radionuclide in domestic and wild birds (pCi/g)
IR_{soil}	=	Ingestion rate of soil (kg/day)
IR_{sed}	=	Ingestion rate of sediment (kg/day)
IR_{river}	=	Ingestion rate of river water (kg/day)
IR_{seep}	=	Ingestion rate of seep/spring water (kg/day)
IR_{fish}	=	Ingestion rate of fish (kg/day)
IR_{leafy}	=	Ingestion rate of above-ground vegetation (kg/day)
IR_{root}	=	Ingestion rate of root vegetables (kg/day)
IR_{meat}	=	Ingestion rate of meat (kg/day)
IR_{milk}	=	Ingestion rate of milk (kg/day)
IR_{eggs}	=	Ingestion rate of eggs (kg/day)
IR_{bird}	=	Ingestion rate of domestic and wild birds (kg/day)
EF	=	Exposure frequency (day/yr)
ED	=	Exposure duration (yr)
CF	=	Unit conversion factor (1000 g/kg)
DF6	=	Ingestion dose factor (rem/pCi)

This equation should be applied twice - once for children age 0-6 and once for adults, and the results summed.

Each of the concentration values may need to be estimated from a basic environmental measurement using concentration ratios, bioaccumulation factors, or other related techniques.

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